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Influence of annealing temperature on the electrical and structural properties of palladium Schottky contacts on n-type 4H–SiC

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ABSTRACT

We have investigated the electrical and structural properties of Pd/4H–SiC Schottky diodes as a function of annealing temperature using *I–V*, *C–V*, AES and XRD measurements. The barrier height (BH) of the as-deposited Pd/4H–SiC Schottky diode is found to be 0.71 eV (*I–V*) and 1.18 eV (*C–V*), respectively. When the Pd/4H–SiC Schottky diode is annealed at 300 °C, a maximum BH is achieved and corresponding values are 0.89 eV (*I–V*) and 1.30 eV (*C–V*). Further, an increase in annealing temperature up to 400 °C, the BH decreases to 0.81 eV (*I–V*) and 1.20 eV (*C–V*). Using Cheung's functions, the barrier height (ϕ_b), ideality factor (n), and series resistance (R_s) are also calculated. Experimental results clearly indicate that the optimum annealing temperature for the Pd Schottky contact to 4H–SiC is 300 °C. According to the Auger electron spectroscopy (AES) and X-ray diffraction (XRD) results, the formation of interfacial phases at the Pd/4H–SiC interface could be the reason for the increase or decrease in BH upon annealing at elevated temperatures. The overall surface morphology of the Pd/4H–SiC Schottky diode is fairly smooth upon annealing temperatures.

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1. Introduction

Silicon carbide (SiC) is one of the most promising and attractive wide band gap semiconductor materials for high-power, high-temperature, and high-frequency applications because of its superior properties over silicon material [1–2]. The breakdown electric field and thermal conductivity is much higher than silicon. Further SiC is probably the only compound semiconductor that forms an oxide layer on reaction with oxygen very much like Silicon. Hence tremendous research have been carried out in the development of SiC based high-power devices. For high temperature and high power applications, a thermally stable Schottky contact on SiC is essential.

Several studies [3–5] revealed that Schottky contacts to SiC exhibit non-idealities and Schottky barrier inhomogeneities. Thermal annealing has been reported to be a necessary step to improve the diode characteristics. For example, Khanna et al. [6] reported that thermal annealing favored the Pt/4H–SiC contact formation which results in the increase of barrier height from 1.07 eV (*I–V*) to 1.40 eV (*I–V*) for the as-deposited and annealed at 400 °C contacts. Perez et al. [7] studied Ni/Ti Schottky contacts on 4H–SiC and reported a barrier height of 1.28 eV and ideality factor of 2.1 eV for the as-deposited contact by current–voltage (*I–V*) measurement. Further, they reported that upon annealing at 900 °C the barrier height and ideality factor improved to 1.25 eV and 1.5 respectively. Han et al. [8] reported a thermally stable IrO_2 Schottky contact on n-type 4H–SiC was achieved by annealing an Ir contact under O_2 ambient. They reported the Schottky barrier height of 1.84 eV (*I–V*), 1.92 eV (*C–V*) for the as-deposited contact and 1.95 eV (*I–V*), 2.22 eV (*C–V*) for the contact annealed at 300 °C under O_2. Oder et al. [9] investigated Schottky contacts on n-type 4H–SiC using ZrB_2 scheme and found that the Schottky barrier height determined by *I–V* measurements, increased from the value of 0.87 eV to 1.07 eV when the deposition temperature is changed from 20 °C to 600 °C. Roccaforte et al. [10] studied the effect of annealing temperature on structural and electrical properties of Ni/Ti Schottky contacts on SiC. Based on the XRD analysis, they reported that the nickel silicide phases gradually transform into the most stable one (Ni_2Si), which resulted in an increase of the barrier height.

The interfacial reactions between the metal and semiconductor plays significant role in determining the quality of the resultant Schottky barriers in SiC as in other compound semiconductor systems. Low leakage current, high Schottky barrier height (SBH) and good thermal stability in Schottky contacts play key role in many electronic and optoelectronic devices. In the present work, Pd was selected since it has a high work function 5.12 eV, and reactivity with SiC. Further, palladium Schottky contacts are important as it can detect hydrogen and hydrocarbon gases at elevated temperatures with high sensitivity [11–12]. In this work, the influence of annealing effects on the electrical and structural characteristics of Pd Schottky contacts on n-type 4H–SiC have been investigated before and after annealing at 400 °C. The diode parameters like ideality factor and Schottky barrier height are determined from the current–voltage (*I–V*) and capacitance–voltage (*C–V*) characteristics as a function of annealing temperature.

2. Experimental details

Schottky barrier diodes have been fabricated on n-type 4H–SiC (0001), 8° off Si face epiwafer with epitaxial layer. The carrier concentration obtained by means of Hall measurement is about $\sim 2 \times 10^{15}$ cm^{-3}. Prior to metal deposition for making Schottky and ohmic contacts, the wafer was degreased in organic solvents like trichloroethylene, acetone and methanol in an ultrasonic bath for 10 min each step and rinsed in deionized (DI) water. Then, the samples were immersed in a solution consists of 1:1:5 ratio of HCL, H_2O_2 and H_2O heated to a temperature of 75 to 85 °C for 10 min to remove the organic impurities followed by rinsed in deionized (DI) water. After this the samples were dipped into a HF solution for 10 sec, blown dry with N_2 gas. Ohmic contact was realized on the c-face by the deposition of Ni (300 Å) using a e-beam evaporation system in vacuum range of 10^{-6} Torr and annealed at 600 °C in a nitrogen ambient for 5 min. Thus, formation of ohmic contacts to SiC with low contact resistivity can be achieved by reducing the barrier height, or/and increasing the SiC surface doping density so that the barrier width becomes thin enough for carriers to tunnel through. Then, 300 Å thick Pd Schottky dots with a diameter of 1 mm were deposited on the wafer using a e-beam evaporation